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The effects of drafting on stroking variations during swimming in elite male triathletes

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Abstract The aim of this study was to determine the effects of drafting behind another swimmer on the metabolic response and stroke characteristics. Six highly trained male triathletes performed two maximal 400-m swims, one in a drafting (D) and one in a non-drafting condition (ND). Their metabolic response was assessed by measuring the oxygen uptake (V̇O₂) and the blood lactate concentration at the end of each 400 m. Swimming velocity, stroke frequency, stroke length, and stroke index (velocity multiplied by stroke length) were recorded every 50 m. In the D and ND conditions, there was no difference in V̇O₂ [66.7 (1.7) ml · kg⁻¹ · min⁻¹ vs 65.6 (1.2) ml · kg⁻¹ · min⁻¹, respectively], however, the lactate concentrations were lower in D than in ND [9.6 (0.9) mM vs 10.8 (0.9) mM, respectively, P < 0.01]. In D, the performance [1.39 (0.02) m · s⁻¹ vs 1.34 (0.02) m · s⁻¹, respectively, P < 0.01] and the stroking parameters (i.e., stroke length and stroke index) increased significantly, while the stroke frequency remain unchanged. In D, a stable pace was maintained, while in ND, velocity decreased significantly throughout the 400 m. In D, the performance gains were related to the 400-m D velocity (r = 0.78, P < 0.05), and to the body fat mass (BFM, r = 0.99, P < 0.01). The stroke index in D was also related to BFM (r = 0.78, P < 0.05). Faster and leaner swimmers achieved greater performance gains and stroke index when drafting. Thus, drafting during swimming increases the performance and contributes to the maintenance of stable stroking parameters such as stroke frequency and stroke length during a 400-m swim.

Key words Blood lactate · Exercise · Oxygen consumption · Performance · Swimming technique

Introduction

In 1995, the International Triathlon Union changed the rules to allow drafting during cycling (i.e. cycling directly behind another cyclist). In the swimming part of the triathlon, drafting has also become more important. Indeed, triathletes attempt to swim as fast as possible to stay in the leading group. In drafting swimming, it has been demonstrated that the metabolic demand is modified (Basset et al. 1991), as in cycling (McCole et al. 1990; Olds et al. 1995), cross-country skiing (Biolo et al. 1994, 1995), kayaking (Gray et al. 1995) or speed-skating (Rundell 1996). In addition, it has been shown to improve the subsequent running performance when used during the cycling part of a triathlon (Hauswirth et al. 1999).

Chatard et al. (1998) showed that swimming behind a leader results in an increase in swimming velocity (by 3.2%) and stroke length, and a reduction in blood lactate concentration and stroke frequency. These authors found that the performance gain was related to the ability of the swimmer and his/her skinfold thickness, with faster and leaner swimmers achieving a greater performance gain.

In swimming, performance and energy cost are related to stroke frequency and stroke length (Costill et al. 1985; Craig et al. 1985; Chatard et al. 1990a; Wakayoshi et al. 1995). Chollet et al. (1997) demonstrated that elite swimmers maintain a constant pace with constant
velocity, stroke frequency and stroke length throughout a 100-m freestyle performed in real competition. Similar findings have been found for running, where small changes in velocity, stride frequency, and stride length, have been related to higher efficiency, lower energy cost and better performance (Cavanagh and Williams 1982; Martin and Morgan 1992).

Thus, triathletes need to be as efficient as possible in swimming to save energy for the cycling and running stages. However, the stroking characteristics used during drafting versus non-drafting swimming have never been investigated. The present study was undertaken primarily to investigate the metabolic response and the stroking characteristics used during drafting swimming.

Methods

Subjects

Six internationally ranked male triathletes participated in this study. All of the subjects agreed to participate voluntarily and gave their written informed consent. Approval for the project was obtained from the University Committee on Human Research. The measurements were made over a 3-day period, at the same time each day, for each experiment in drafting (D) and non-drafting (ND) situations.

Anthropometric measurements

After measurement of the subjects’ height and body mass, body fat content was estimated from the skinfold thickness, expressed in mm, and representing the sum of four different sites (biceps, triceps, subscapula and supra-iliac) measured on the right side of the body with Holtain calipers, following the method described by Durnin and Rahaman (1967). On average, three independent measures were taken of each fold. If the second measure was not within 5% of the first, subsequent folds were measured until two folds within 5% were retained. The equation of Durnin and Rahaman (1967) was used to determine the percentage of body fat mass (BFM). Lean body mass (LBM) was determined from body mass and BFM. The subject’s buoyancy was evaluated by the measurement of the hydrostatic lift (HL; Chatard et al. 1990b). The HL corresponds to the force that enables the swimmers to float when they are immersed while in forced inspiration, and was measured at the end of a maximal inspiration when subjects were floating. The subjects were in the fetal position, facing downward. A lead mass, varying in weight from 0.1 kg to 1 kg, was applied to their back at the level of the shoulder blades. The final load necessary to maintain the subjects in a balanced position just under water was considered as the HL. This method has been shown to be highly reliable ($r = 0.98$ for eight swimmers) and easy to apply (Chatard et al. 1990b).

Swimming performance

After a 15-min warm up, swimming performance was measured first in a ND situation in a 50-m pool, with each subject starting in the water, without diving. The water temperature was 26–26.5 °C. In this situation, the subjects swim alone for 400 m at a maximal velocity. Two days later, the subjects swim another maximal 400 m in a D condition, in the same lane but behind a competitive swimmer. The lead swimmer was wearing a pull-buoy to avoid the water turbulence caused by movements of the feet. For the first 200 m, the lead swimmer was instructed to follow a pace at least 3 s faster than for the first 400 m of the drafting triathletes. The pace was set for the lead swimmer by an observer walking along the side of the pool at the required speed. For the last 200 m, the triathletes could touch, if necessary, the lead swimmer’s feet to indicate that he was to swim faster. The same lead swimmer was used for all of the subjects. The drifter was instructed to be as close as possible to the lead swimmer. The order of the 400-m trials could not be randomized, as the performance time in the first 200 m of the ND trial had to be established to set the pace for the first 200 m of the D trial. However, it is unlikely that a training effect could have occurred between both trials, since they were only separated by 2 days, and each subject’s training was similar in volume and intensity during the day preceding each trial. However, a familiarization effect with the trial could not be ruled out.

Stroke frequency, stroke length and stroke index

During the 400-m swims, subjects were instructed to keep as constant a pace as possible. The stroke frequency, expressed as the number of complete arm cycles per min, was measured for each 50 m, with a frequency meter on three complete stroke cycles, four times per 50 m. A mean value was retained for each 50 m. The stroke length was calculated by dividing the mean velocity of each 50-m swim by the mean stroke frequency of each 50 m. The stroke index was calculated by multiplying the velocity by the stroke length (Costill et al. 1985). This index assumes that at a given velocity, the swimmer who has the greatest stroke length has the most effective swimming technique and skill (Costill et al. 1985).

Expired gas analysis

Oxygen uptake ($V_O_2$, in l · kg⁻¹ · min⁻¹) was measured from the expired air collected during 20 s after the completion of the maximal 400-m front crawl swims. The method used, which was introduced by di Prampero et al. (1976), has also been described by others (Lavoie et al. 1983; Costill et al. 1985; Montpetit et al. 1988; Chatard et al. 1995). Swimmers were free from equipment. Expired gases were collected in a Douglas bag using a Daniel’s breathing valve. Oxygen and carbon dioxide fractions were determined using Beckman OM 11 and LB 2 gas analyzers (Fullerton, USA) and calibrated prior to analyses with gases of known concentrations. Volumes were measured with the aid of a Tissot spirometer (Techmachine-Gymrol, Andrézieux-Bouthéon, France). This method has been found to be valid ($r = 0.97$, standard error of the estimate $= 0.238 l · min^{-1}$ for 20 swimmers; Chatard et al. 1995) and reliable, the reliability coefficient being between 0.92 and 0.97 (Costill et al. 1985; Montpetit et al. 1988).

Post-exercise blood lactate concentration

Two blood samples were taken at the finger extremity after the 1st and the 3rd min following the 400-m swims. Lactate concentrations were measured by an electroenzymatic method with a lactate analyzer (Cétric, Toulouse, France), using the method of Geysseant et al. (1985). Of these two samples, the highest concentration was retained. Blood lactate was considered a good means of estimating the level of exercise intensity and the anaerobic energy release (Lacour et al. 1990; Capelli et al. 1998).

Energy cost of swimming

The energy cost of swimming (mO₂ · kg⁻¹ · min⁻¹) was calculated from the ratio of the overall metabolic power output, expressed in mO₂ · kg⁻¹ · s⁻¹, to the speed in m · s⁻¹. In turn, the overall metabolic power was obtained from the sum of the $V_O_2$ above resting (assumed equal to 4 mO₂ · kg⁻¹ · min⁻¹) and the rate of anaerobic energy release. This was assumed to be proportional to the rate of blood lactate accumulation per unit of time, on the basis of an energy equivalent of 3 mO₂ · kg⁻¹ · nM⁻¹ (di Prampero 1981; di Prampero and Ferretti 1999).